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type of art-expression existed, which seems to show a remarkable resemblance to those Old-World forms which reached its culmination in the classical type of the Mediterranean peoples.

A study of these features of ceramic art enables us to draw many interesting and important conclusions. At times, as in the case of the reappearance of the same forms similarly treated in the stone graves of Tennessee and the mounds of Missouri and Arkansas, we are led to the view that they had, at least, a point of contact. In other instances we have evidence of migrations, while, again, in other cases, where both contact and migration are out of the question, we are able to trace the development of that innate principle of the human mind which, among all peoples, finds its expression in ornament and art. We see that the artistic powers of man, like the languages, were developed in distinct centres, and from primitive forms of expression, which, of necessity, had principles in common; and this will amply account for the reappearance of the same forms in widely-separated regions. The early methods of ornamentation of pottery were by finger-marks, scratches, cross-lines, and the impression of cords and fabrics, and these are found almost the whole world over. It is only when steps in advance are taken that the art of each nation receives its distinctive impress.

COMPARATIVE CHEMISTRY OF HIGHER AND LOWER PLANTS.[1]

BY HELEN C. DE S. ABBOTT.

ON coming before a popular audience to present a special subject like Plant Chemistry, I do so in hopes perhaps of showing some of the less familiar sides of plant-life. The chief idea of the remarks I am about to make is one that has not occupied to any great extent the minds of botanists and chemists, and if it be not true, at least, no other hypothesis has been suggested than the one I will indicate to account for the chemical compounds of the vegetable kingdom.

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[1] Lecture delivered in the course given under the auspices of the Philosophical, Anthropological, and Biological Societies in the United States National Museum, Washington, April 23, 1887.

On past occasions[1] I have spoken of certain chemical compounds in relation to plant morphology and evolution. The facts then advanced tended to show a chemical progression in plants, and a mutual dependence between chemical constituents and change of vegetable form, and in the following pages I will keep this idea prominently before you.

Certain condensations of force on our planet are known as chemical bodies. By usual methods they cannot be split up into component parts, hence are denominated elements. However, we have reason to believe that these so-called elements are in reality compounds themselves, formed in the cosmic laboratory from still simpler aggregations of matter.

In mineralogy the series of chemical formations are doubtlessly the result of evolution, from the more simple elements to the complex structure of the crystalline rocks.[2]

The plant kingdom may be considered as a third and higher stage; it contains in its structure combinations of the elements carbon, hydrogen, nitrogen, oxygen, sulphur, phosphorus, and compounds derived from the mineral world.

The essence which underlies all force and life may be traced through these three planes as a law of progression, little varying in its general course, though ever giving more involved problems for solution, according to the increasing complexity, from elements and minerals to plants, and even to animals.

The line separating each of these conditions of matter is indistinct, "the individual of the one encroaches upon the dominion of the other;"[3] as a spiral coil is of a single thread, so "nature in all her manifestations constitutes a unity,"[4] and the rounds of the spiral present each stage parallel, but in reality a continuation.

Analogies should not be given too much weight, but from numerous facts the above statements seem theoretically reasonable and may be provisionally accepted. The possibility of chemical evolution of the elements, in itself, is not only one of the most absorbing questions of the moment for investigation, but the evolution of compounds from these elements and their possible influence upon the external forms of plants is of equal interest.

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[1] "Certain Constituents of Plants considered in Relation to their Morphology and Evolution." Read before the Chem. Sec. of the A. A. A. S. at Buffalo, 1886. Abstract published in the *Botanical Gazette*, vol. xi., October, 1886. "The Chemical Basis of Plant Forms." Lecture delivered before the Franklin Institute, Philadelphia, 1887. *Franklin Institute Journal.*

[2] Mineral Physiology and Physiography. By T. Sterry Hunt. Boston, 1886.

[3] The Chemical Basis of Plant Forms. By Helen C. De S. Abbott.

[4] T. Sterry Hunt, page 18.

That directive force which controls the different groupings of atoms in a molecule under the solid, liquid, or gaseous forms of matter, manifests itself in still more complicated conditions in each grade of the chemical compounds of living cells, and thus from the single cell to the highest of plants is ever active.

It is not my wish to claim for plant chemistry more than the facts at my disposal will allow; though in the past, and this should not be overlooked, without the aid of the imagination to penetrate the avenues of the unknown, many of our well-established scientific facts would still be buried from sight.

The chemical analysis of the dead plant and the study of the chemical changes occurring in the living plant are among our means for some of these investigations; and much of all the knowledge derived from each field of chemical research may be utilized in aiding to unravel the mystery of these changes in the vegetable cell.

In the mineral kingdom certain elements are invariably associated with others, as nickel with cobalt; and in plants we find not only two or more compounds invariably present together,—*i.e.*, tannin and starch in the tannin groups, lime and saponin in the pink family, Caryophyllaceæ,[1] resins and saponin in all of the saponin-containing groups, and sugar and silica in the grasses, Gramineæ,—but also in certain plant groups we notice the predominance of special compounds, and their absence in other groups. The grouping of these compounds in definite association must bear some relation to their respective sequence and formation, and cannot be the result of accident. That the cinchona plant does not manufacture the alkaloids of the poppy, but each its own particular series of compounds, illustrates this.

I have said, elsewhere,[2] "the chemical compounds of plants do not occur at random. Each stage of growth and development has its own particular chemistry. . . . The result of experiment shows that the presence of certain compounds is essential to the vigor and development of all plants, and particular compounds to the development of certain plants." It may be inferred that "plant chemistry and morphology are related. Future investigation will demonstrate this relation."

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[1] Die Pflanzenstoffe, by Hilger and Husemann, p. 532; E. v. Wolff, J. pr. Chem., li. 24; lii. 86; Wolff, Aschenanalysen, 1881, 144, 145.

[2] The Chemical Basis of Plant Forms.

The theory of evolution, which underlies all mineral and organic forms, comprises the evolution of the component parts of the whole, and, since the structural bases of minerals and plants are chemical compounds, their evolution must necessarily be included in a study of plant-life. Whether this life reveals itself in the perfume of sweet flowers, or in the manifold forms of vegetation, from the simple mass of plant-jelly to the majestic forest-tree, its dependence upon matter invokes the most eager desire to acquaint ourselves with its various manifestations.

When matter, through chemical change, exhibits properties of absorption, metabolism, excretion, reproduction, contractility, automatism, and irritability, it is said to be living. In this condition it is called protoplasm. This substance is very complex and of undetermined composition, though its proximate constitution is known.[1] It is always present where life, as defined, is found, apparently the same in the lower as in the higher plants.

The lowest forms of plants, plasmodia, are irregular-shaped masses of jelly, undifferentiated in form, function, and chemical composition. This living jelly is described "as a colloidal albuminoid united with more or less water."[2]

Plant-cells, when alive, are composed of a semi-fluid albuminous substance very like the plasmodia, closed on all sides, with a watery liquid holding salts and saccharine substances in solution, and lying in contact with a firm elastic membrane called the cell-wall; also, like it, closed on all sides, and consisting of cellulose, water, and inorganic matter. Some of the Algæ and all higher plants are congregations of these cells grouped as tissues and organs, and their albuminoid contents are undergoing continual change; in life it is a building-up process, the food being supplied from the gases, water, and inorganic substances of the surroundings, and elaborated in the plant's own laboratory to meet its needs.

The vegetable kingdom does not usually claim our attention for its intellectual attainments, although its members would certainly seem to possess greater chemical skill than a higher race of beings exhibit in their laboratories. Some few of this higher race are "going to take lessons" how to construct proteids and carbo-hydrates as we are told our now automatic cousins were once taught to do; though man fails to consider that it may be a lost art, and the secret has died with the plants in a "catagenetic" decline.

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[1] Reinke and Rodewald, Berlin, 1881; Physiological Botany, by G. L. Goodale, 1885, p. 197.

[2] T. Sterry Hunt, Min. Phys. and Physiography.

All plants and their products are composed of two general classes of compounds,—volatile and fixed. The former, on incineration of the plant, is transformed into gases, leaving the last as so-called ash-constituents.

I will very briefly refer to the sources of the substances which go to the building of the plant structure. Green plants derive their carbon from the carbon dioxide of the atmosphere, and even from complex organic compounds, since Darwin[1] has shown that insectivorous plants, by means of their modified leaves, are able to absorb flies and other small insects.

Plants which do not contain chlorophyll, as fungi, take their carbon from complex compounds of decaying organic matter. Not only do all the so-called organic compounds of plants contain carbon, but it is found also in the form of carbonates.[2]

Hydrogen is absorbed by all plants in the form of water, or ammonia and its compounds, or in complex substances, as mentioned above. Oxygen is taken up by plants free or in combination in water or in salts, and there are six possible sources of nitrogen supply; but I will not delay by going into this subject.[3]

Sulphur and phosphorus are constituents of proteids, and are derived from inorganic compounds. In addition to these the elements essential to the nutrition and maintenance of the life of all plants are potassium, calcium, magnesium, iron in the case of green plants, its absence producing the condition of etiolation; and, in certain cases, chlorine. Silicon, fluorine, manganese, sodium, lithium, rubidium, cæsium, barium, strontium, aluminium, zinc, copper, arsenic, titanium, iodine, and bromine have also been found among the ash-ingredients of certain plants.

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[1] Insectivorous Plants.

[2] Ann. Phys. et Chim., Berthelot.

[3] The Economical Aspect of Agr. Chem., by H. W. Wiley, Proc. A. A. A. S., vol. xxxv., 1886.

These ash-ingredients are usually present in each plant-cell, in the cell-wall, imbedded in the cellulose and partly in the contents of the cell. The salts of the alkaline metals, sulphates, chlorides of magnesium and calcium, also soluble silicic acid, as in *Equisetum hiemale*,[1] occur in solution in the cell-sap, and insoluble salts exist in the tissues of plants.

The differences in the composition of the ash of plants show that each plant is endowed with a specific absorbent capacity; thus a gramineous plant[2] is able to withdraw relatively larger quantities of silica from the soil than a leguminous plant. The latter can only do so to a very slight extent.

The absorbent capacities of allied species are very different. Again, individuals of the same species yield different ash-constituents, depending upon their vigor, and at different periods of growth the ash-composition varies. In a summary of experimental results it has been stated that[3] "similar kinds of plants, and especially the same parts of similar plants, exhibit a close general agreement in the composition of their ashes, while plants which are unlike in their botanical characters are also unlike in the proportions of their fixed ingredients."

Certain marked varieties of plants appear to be peculiar to and developed by certain soils, as the violet, *var. calaminaris*, and the penny cress, in zinc soils.[4] In the leaves of the latter plant thirteen per cent. of zinc oxide was found, and I have found manganese in the different portions of *Yucca angustifolia*[5] grown near Lake Valley, New Mexico.

Plants may absorb from the soil mineral matters independently of their use or harmfulness to the plant, but the absorption of essential inorganic constituents will depend upon their relation to the changes in the vegetable cell.

The ash-constituents of a plant increase from the roots upward to the leaves, the largest percentage being found in the younger portions of the growing plant, and I have observed this same principle on a more general scale running through the entire plant kingdom, for the largest ash-percentages are found among those plants lower in the evolutionary scale, which would correspond to the larger ash-percentage of younger, or formative, parts of the growing plants. Some of these lower groups, as the diatoms of the Algæ and the vascular cryptogams,[1] contain enormously large ash-percentages; in the Horse-Tail, *Equisetum*,[2] 60 per cent. alone of silicic acid. The *Lycopodium*,[3] in addition to 14 per cent. of silicic acid, contains 27 per cent. of alumina and 2.5 per cent. of manganese. Among comparatively lower plants the willow and poplar[4] are rich in ash-constituents; the former[5] contains 1.53 per cent. of manganese. Members of the sedge order and grasses contain large quantities of silica; the rice-hull, 98 per cent. Various species of apetalous plants on the same evolutionary plane with these groups also contain a large percentage of ash-constituents, as the *Salicornia*, *Salsola*, *Chenopodium*, and *Atriplex*, also the Sugar-Beet.

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[1] Lange, Ber. d. deut. chem., Ges. xi.

[2] Wolff, Aschenanalysen, 1871.

[3] How Crops Grow, by S. W. Johnson, London, p. 145.

[4] A. Braum and Risse, Sachs, Exp. Physiologie, 153.

[5] Amer. Phil. Soc. Trans., H. C. De S. Abbott.

I have stated what chemical elements are essential for the life of the lower, as well as the higher, plants; also those which may occur in certain plants; and I have spoken of the two general classes of compounds of which plants are built as the volatile and ash constituents. The four elements carbon, hydrogen, oxygen, and nitrogen enter into the composition of the first class of compounds, and the grouping of these elements with each other and to the ash-elements constitute what is called plant chemistry.

As certain chemical elements are always present in plants, so certain changes occur and compounds are found generally, more especially among the albuminous constituents. However, even this statement should be restricted to saying that the first chemical reactions between these elements are probably identical at the start, the subsequent compounds formed depending upon the evolutionary stage.

The infinite variety of these compounds is only equalled by the numerous genera and species of the vegetable kingdom; though certain compounds frequently occur, as starch, sugar, tannin, and other bodies, correlated in special groups of plants with special and distinct properties. For example, the true starch of the cryptogams will be found gelatinous in Algæ, replaced in Fungi as glycogen, and only in the lowest of the flowering plants does it occur in the simplest stratified form; from this stage to the highest of plants, the Compositæ, in which it occurs as a crystalline substance called inulin, it may be traced from plane to plane of plant-group development in a succession of stratification until it reaches its highest point in our most evolved plants. So strongly marked are these varieties of starch-forms that some investigators, notably Nägeli, have proposed this means for the identification of many plant families.

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[1] Die Pflanzensenstoffe, p. 323, W. Lange; Bil. Ver., xi. 822.

[2] Ann. Chim. Phys., xi. 62, 208; Ann. Chim. Pharm., 77, 295.

[3] Flückiger, Pharmacognosie, Kamp; Ann. Chim. Pharm., 100, 300.

[4] Durocher and Lalaguti, Liebig's agric. Chemie, 8 Aufl., 371.

[5] E. Riechardt, Chem. pharm. Centralbl., 268, 567.

The many kinds of vegetable sugars known to chemists also have their locations, not only during different stages of the individual plant-growth and in different parts of the plant, as synanthrose,[1] the especial sugar of the unripe grain of rye and wheat, but also in certain families, some one kind of sugar will predominate in many of the individuals. The tannins of the oak, beech, and poplar are not those of the higher plants.

At a certain stage of plant evolution, glucosides, substances capable of splitting up and yielding, among other products, sugar, appear. I have observed in those plants where large percentages of such substances are found a diminished proportion of starch and sugar,[2] or their absence, notably in soap-bark and species of the *Yucca.*

The waxes, oils, camphors, resins, acids, and other classes of vegetable compounds might be similarly cited as offering characteristic properties in various plants in which they appear, but the examples given are ample to illustrate my point, that the chemical compounds of plants should be considered from three sides, viz.:

1. In their own development through many plant groups from a gelatinous or undifferentiated compound to a polymer, or a substance of the same chemical formula having a solid or crystalline form.

2. In their succession of changes which may be observed during the different stages of the individual plant's growth, and the relation of these chemical changes to other compounds present in the plant.

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[1] Ripening of Seeds, by A. Muntz, Ann. Agronom., xii. 399, 400; Jour. Chem. Soc., Feb. 1887, p. 173.

[2] Trans. Amer. Phil. Soc., *Yucca angustifolia.*

3. The location as predominant of some one or associated compounds only in certain plants on similar evolutionary planes.

These three conditions correspond to what was stated at the beginning, that a law of universal progression may be traced wherever matter or force exists.

There is no absolutely certain knowledge of the precise character of the chemical changes which these plant compounds undergo, though we have some information about them. Investigations are being vigorously pushed in this department of plant-life, and it may be reasonably inferred that definite facts will be obtained on many of these subjects.

It would seem from the latest researches that the albuminous or proteid compounds to which life is essentially linked are formed from a compound containing nitrogen, called an amide, and some carbo-hydrate; its sulphur and phosphorus supply being derived from inorganic sources. This amide is probably asparagine or a related body. Various suggestions have been offered to explain its formation in the plant, from the breaking down of protoplasm to its construction from simple nitrogenous and carbon compounds, and among the latest investigations,[1] the results show that the formation of asparagine is independent of carbo-hydrates, and that the amide formed is not a by-product of the interchange of matter within the plant. The author of these experiments considers that asparagine is formed by the union of inorganic nitrogen compounds and malic acid within the plant, the acid being derived from the carbo-hydrates.

Other nitrogenous compounds, as the alkaloids, for example, are probably formed from the complex albuminoids, and in fungus plants which are especially rich in nitrogenous compounds alkaloids are common.

It has been generally held that alkaloids with resins and some other compounds occurring in plants are waste products, but this cannot be accepted as final. The researches[2] of Selmi, Gautier, Etard, Brieger, and others have broken down an imaginary distinction between plants and animals which is of interest in this connection. They show that the production of alkaloids is a general function common to all living cells, whether they be Bacteria or the cells of living animals.

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[1] O. Müller, Landw. Versuch. Stat., 1886, 326–335; Jour. Chem. Soc., p. 70, Jan. 1887.

[2] Les Alcaloides d'origine Animale. Par Dr. L. Huhouneng, Paris; Chem. News, Dec. 10, 1886.

In the animals with their excretory functions these poisonous substances would be readily eliminated from the system, but it seems to me that in the absence of homologous organs in plants these compounds might be used again for the building up of tissue and prevent the accumulation of products detrimental to plants, and the recent investigations of Kellner[1] on the composition of tea-leaves show that this view is not unlikely, for he states that the non-albuminoid nitrogen is almost wholly absent during the latter stages of growth, being found as theine; in the seeds the albumen has increased, but no theine is found, thus the author believes that positive proof is afforded that the alkaloids are a decomposition product of albumen, and capable of again forming albumen like asparagine and glutamine.

It will not be possible in this place to enter more fully into the details of the chemical changes going on within the plant. My time will not allow a discussion of the changes of starch into sugar, and conversely, nor a review of the many steps in the transformation of protoplasm into the simpler products of cellulose, chlorophyll, and other substances; and it may be well to say that the ideas of physiologists in regard to these changes are unstable, since the acquisition of new facts seems to unsettle former opinions. But, to illustrate the revolution within the last few years from former views held in plant chemistry, I will mention that sugar is not, in all plants, a reserve or plastic body, and in some few (for example, the sorghum-cane[2]) it must be regarded rather as a waste product, and its advent in larger percentage after the maturity of growth marks the decay of the plant and attends its euthanasia.

I have desired, by entering into all of the above particulars, to prepare for a consideration of the compounds which are formed by these chemical successions and occur through the plant kingdom. In treating of this subject I shall have so frequent occasion to speak of the different plant families that, for convenience, I shall use the order of evolution for flowering plants proposed by M. Édouard Heckel,[3] and which is represented in the table.

[1] Landw. Versuch. Stat., 1886, 370, 380; Jour. Chem. Soc., Jan. 1887, p. 73.

[2] On the Variations of Sucrose in Sorghum Saccharatum, by H. W. Wiley, Botanical Gazette, vol. xii., March, 1887.

[3] Revue Scientifique, 13 Mars, 1886.

SCHEME OF PLANT EVOLUTION.

By M. Édouard Heckel.

Processes.		*Apetalous.*		*Monocotyledons.*	*Dicotyledons.*	
					Cupuliflores.	*Thalamiflores.*
Simplicity of Floral Elements.	Amentales.	Casuarineæ, Myriceæ, Juglandeæ, Salicineæ, Carylaceæ, Cupuliferæ, Betulaceæ, Balsamifluæ, Plantaneæ.	Fluviales.	Lemnaceæ, Naiadeæ, Potameæ.		
	Spadiciflores.	Piperaceæ, Ceratophyllaceæ, Chloranthaceæ, Saurureæ, Datisceæ, Nepentheæ.	Spadiceæ.	Jugcagineæ, Aroideæ, Pandaneæ, Cyclantheæ, Palmea, Typhaceæ.		
Metamerization. Multiplicity of Floral Elements.	Monimo-Urtico Polygonales.	Monimiaceæ, Urticeæ, Cynocrambeæ, Canabineæ, Ulmaceæ, Celtideæ, Moreæ, Polygoneæ, Amarantaceæ, Baselleæ, Chenopodeæ, Artocarpeæ.	Glumoideæ.	Cyperaceæ, Gramineæ, Restiaceæ, Eriocaulaceæ, Xyrideæ, Junceæ, Commelyneæ.	Rosales, Ficoids.	Polycarpels, Hydropeltideæ.
	Daphnales.	Phytolacceæ, Laurineæ, Myristicaceæ, Santalaceæ, Loranthaceæ, Cytineæ, Balanophoraceæ, Begoniaceæ, Elæagneæ, Proteaceæ, Thymeleæ, Nyctagineæ.	Liroideæ.	Liliaceæ, Irideæ, Alismaceæ, Butomeæ, Hydrocharideæ, Pontederaceæ, Taccaceæ, Bromeleæ, Tillandsiæ, Musaceæ, Zingiberaceæ, Cannaceæ.	Saxifrages.	Cruciformes-Euphorbiales, Parietales, Tilio-Malvales, Gamopetelous-Isogynes.
					Leguminous plants, Rhamnals, Bicarpels.	Gamopetalous-Anisogynes, Labiatiflores.
Cephalization. Simplification of Floral Elements.	Serpentaires.	Asarineæ, Aristolochiaceæ.	Gyandres.	Apostasiaceæ, Orchideæ.	Apocyneæ, Asclepiadeæ.	
					Epicorolliflores. 1. Corysanthérie.	Caprifoliaceæ, Campanulaceæ, Lobeliaceæ, Valerianeæ, Dipsaceæ.
					2. Synanthérie.	Goodeniaceæ, Brunoniaceæ, Stylideæ, Compositæ.

The author classes all these plants under three main parallel divisions, from the lowest of the apetalous,[1] mono- and dicotyledonous groups to their respective highest plants. These three main columns are divided at the same point into three general planes. On plane 1 are all plants of simplicity of floral elements or parts; for example, the black walnut with the simple flower contained in a catkin. On plane 2 are plants of multiplicity of floral elements, as the many petals and stamens of the rose; and, finally, the higher plants, as the orchids among the monocotyledons, and the Compositæ among the dicotyledonous plants, come upon the third plane, or the division of condensation of floral parts.

These three characteristics, simplicity, multiplicity, and condensation of floral elements, are correspondingly repeated in each of the three horizontal planes, and even in individual orders in their lowest and highest plants.[2] To facilitate the comprehension of this classification I have assembled a sufficient number of the plants themselves, so arranged as to place before you a living representation of this complicated diagram.

(To be concluded.)

HORNLESS RUMINANTS.

BY R. C. AULD.

THE group of mammals known as Ruminants exhibits certain characters more or less dependent and highly typical. Among these is the possession of horns. The Ruminants are the only recent mammals provided with bony extensions of the

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[1] Heckel's division of apetalous plants from mono- and dicotyledonous groups has been criticised by some botanists as an artificial method of classification. Since all botanical classifications have been declared, on botanical authority, in a measure, artificial, the author does not feel called upon to apologize for introducing M. Heckel. She has found his scheme to answer her purposes, provisionally, more fully than other classifications, and she is indebted to him for a means of presenting her subject, which would be otherwise impracticable. Further than this she is not responsible for advocating the classification. M. Heckel's table is published with his paper, "Les plantes et la théorie de l'evolution," in the *Revue Scientifique*, 13 Mars, 1886.

[2] Plate XXV. illustrates this principle for the three horizontal planes, which is also applicable to the orders.